§1. Helium Ash Removal by Moving-Surface PFCs

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Ever since the discovery of the "Supershot" confinement regime in TFTR in late 1980's, it has widely been recognized in the magnetic fusion energy research community that high-performance core plasmas often favor reduced wall recycling, i.e., R≤1, where R is the particle recycling coefficient. To reduce particle recycling, wall conditioning techniques such as boronization have been applied to many plasma confinement experiments. Unfortunately, due to the surface saturation with trapped particles, the efficacy of wall conditioning has a finite lifetime, which necessitates the shutdown of plasma operation for re-conditioning. Clearly, this is not acceptable from the point of view of operating steady state fusion power reactors. It follows immediately from these arguments that enabling wall concepts R&D is necessary for the successful operation of steady state fusion devices beyond ITER.

Over the past decade, therefore, a variety of innovative plasma-facing component concepts have been proposed to provide a resolution for this steady state particle control issue. Essentially, all of these concepts employ moving-surface components, either made of a solid or liquid material, for in-line regeneration of particle trapping capabilities. One such concept proposed by Hirooka et al. [1] features a moving belt made of SiC-SiC fiber fabrics with an in-line getter film deposition system. In our previous work [2], proof-of-principle experiments were conducted on this concept with the moving belt simplified by titanium- or lithium-gettered rotating drums built in the laboratory-scale plasma facilities. Results indicate that hydrogen recycling can be reduced down to levels significantly lower than 100%, even at steady state, so long as gettereing continues.

For the steady state operation of DT-fusion power reactors, not only unburned fuel but helium ash must be removed continuously so as to sustain the nuclear reaction. This means that a substantial pumping speed is necessary for helium ash removal. Given the edge helium partial pressure of the order of 10^{-5} Torr, for example, the power output of 1GW would require a pumping speed as large as 10^{6} liters/s. Although usually cryogenic pumps are employed for hydrogenic fuel particle control in existing large fusion devices, helium cannot be pumped at the same efficiency due to its extremely low boiling point of 4.2K. Unfortunately, the use of turbo-molecular pumps for helium ash removal is not quite realistic because of the conductance loss along the pumping ducts penetrating thick cryostat walls of superconducting magnets, essential for steady state fusion reactors. Nonetheless, helium ash removal has yet to be addressed as a critical issue in the magnetic fusion community.

In the present work, the use of moving-surface plasma-facing components (MS-PFCs) is proposed for the continuous removal of helium ash as well as hydrogenic particles to maintain reduced recycling. It is of particular importance to investigate whether helium and hydrogen can simultaneously be incorporated in lithium deposits.

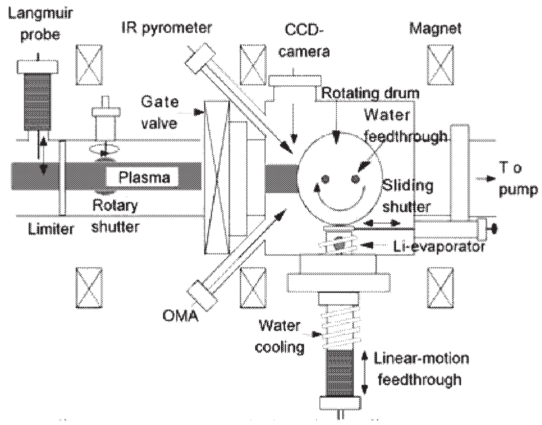

Fig. 1 A schematic diagram of the MS-PFC test unit.

Shown in Fig. 1 is a schematic diagram of the rotating drum MS-PFC test unit built in the VECHILE-1 facility [3]. The rotating drum is made of cupper and is water-cooled. The rotation speed at the periphery is set at 10cm/s. The deposition of lithium is initiated after 100% steady respective state recycling was achieved. The deposition rate is set at about 50Å/s, adjusting the position and temperature of the evaporator.

Results of hydrogen and helium mixture plasma recycling measurements are shown in Fig. 2. Notice that, as soon as lithium deposition starts, steady state recycling of both hydrogen and helium, measured with H_{α} and He-I spectroscopy, exhibits a noticeable decrease of about 20%. These data are suggestive of a multi-phase structure in the lithium-helium-hydrogen system, a hydride in the form of LiH and defect-trapped helium in lithium deposits [4].

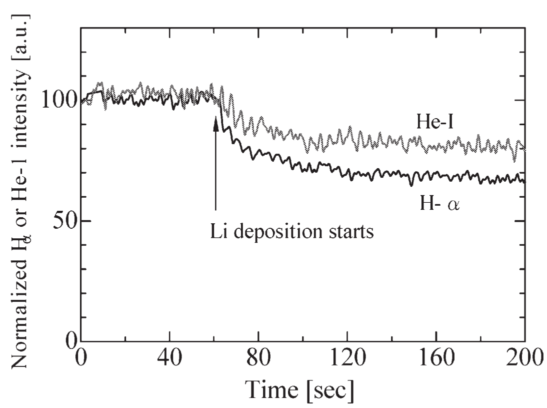

Fig. 2 Reduced steady-state recycling of hydrogen and helium from a lithium-deposited rotating drum.

References

1) Hirooka, Y. et al, Proc. 17th SOFE, Oct 6-10th , 1997, San Diego, pp.906.
2) Hirooka, Y. et al., Fusion Sci. & Technol. **47**(2005)703.
3) Hirooka, Y. et al., J. Nucl. Mater. **337-339**(2005)585.
4) Hirooka, Y. et. al, paper presented at the 17th PSI-conf., May 22nd-26th , 2006, Hefei.